# Growing Wheat in Western Washington

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**Main cover photo by Alysia Greco, Oregon State University; inset photo by Carol Miles**

# INTRODUCTION

Wheat has been grown in western Washington since European settlers first farmed the region in the mid-1800s. As eastern Washington was settled in the late 1800s, large-scale wheat production became well established there, and today we forget that wheat has a history and continued place in farming systems on the west side of the state. Today in western Washington, wheat is grown for 3 primary reasons: 1) as a secondary cash crop; 2) as a rotation crop to break disease cycles with potatoes, vegetables, bulbs, and other primary crops; and 3) as a cover crop to protect and improve soil quality.

The release and availability of wheat varieties with resistance to stripe rust has increased the yield potential of wheat in western Washington in the last 50 years. Today, wheat breeders, pathologists, and local growers are working together to develop and select new varieties that are well suited to the cool wet maritime climate of western Washington. World supply and market conditions are making wheat a more competitive market crop than in the recent past. At the same time, new local markets are providing farmers with opportunities to grow and sell specific varieties or blends. The following guidelines will aid western Washington growers to select varieties and production practices that are best suited to their area to achieve maximum wheat production.

## VARIETIES

Farm management factors such as crop rotation, herbicides, fertilizers, and tillage intensity, as well as local soil and climatic conditions, all influence variety performance. Variety trials are often conducted in conventional production systems with moderate to high levels of inputs such as fungicides, herbicides, fertilizers, and pest management. If your farming system is low input or organic, it is best to test several different varieties for 2–3 years to see which performs best in your system. If your farm includes a diversity of soil types and environmental factors, test the same varieties in multiple locations to see if a particular variety is best suited to a particular field. Environmental factors such as level of soil saturation/drainage, soil pH, and soil organic matter, as well as other factors such as cropping history and carryover nutrients, can significantly impact variety performance. Any one variety may not be best suited to all fields on your farm.

Varietal mixtures help to maintain yield stability over time and across micro-environments. Well-composed mixtures increase the genetic diversity in a field and help buffer against fluctuations in temperature, rainfall, disease, and insect pests. For example, some varieties are high yielding in years of abundant rainfall but drop off drastically in drought years, while other varieties maintain fairly stable yields regardless of rainfall. Varietal mixtures also optimize differences in height (to capture the maximum available sunlight) and extend resistance to diseases such as stripe rust that evolve rapidly. To optimize harvest results and operations, use varieties that have the same harvest maturities.

Table 1 presents several wheat varieties that are either known to grow well in western Washington or have this potential based on specific breeding characteristics. The information can be used to compare with new varieties as they become available. Growing experiments using small areas for side-by-side plantings of familiar and new varieties are the best way to compare relative performance.

Decisions about which varieties to grow also depend on what consumers are looking for. There are 2 major market classes grown in Washington:

1. Hard red—used for making bread; typically has higher protein content and gluten quality than soft white
2. Soft white—used for making flat breads and pastries

**Table 1. Wheat varieties well suited to production in western Washington.**

| Wheat Type | Variety | Disease resistance; Other important features |
|---|---|---|
| *Soft white winter* | Cashup | Resistant to stripe rust |
| | Daws | Resistant to stripe rust |
| | Hyslop | Resistant to stripe rust |
| | Madsen | Resistant to stripe rust |
| | McDermid | Moderately resistant to stripe rust |
| | Paha | Susceptible to some races of stripe rust |
| | Stephens | Resistant to stripe rust |
| | Tubbs 06 | Resistant to stripe rust |
| | Yamhill | Moderately resistant to stripe rust |
| | Xerpha | Moderately resistant to stripe rust |
| *Hard red spring* | Kelse | Resistant to stripe rust, semi-dwarf growth habit |
| | Westbred Express | Moderately resistant to stripe rust, semi-dwarf, very tolerant to lodging |
| | Canus | Historical variety, standard height |
| *Soft white spring* | Louise | Resistant to stripe rust |
| | Wawawai | Moderately susceptible to stripe rust |
| | Beaver | Historical variety, standard height |

There are also several minor market classes: a) hard white for bread, b) durum for pasta, and c) spelt for a wide range of specialty products. The end use of the wheat is a primary factor to consider when deciding which varieties to grow together in a mixture. Combine only varieties within the same market class in the field, as it is extremely labor-intensive to separate them after harvest.

The most commonly planted wheat variety in western Washington is Cashup. Along with Cashup, Stephens and Daws are resistant to stripe rust and are well suited to use in western Washington. Daws has greater winter hardiness than Stephens, which may not be sufficiently cold hardy in some areas. Yamhill has demonstrated reduced yields in northwestern Washington due to stripe rust, but appears well suited to southwest Washington. Hyslop may be used but is not generally recommended due to low productivity.

## SOIL MANAGEMENT

### Seedbed Preparation

Proper seedbed preparation enhances the establishment and growth of a uniform, healthy wheat crop. Excessive tillage breaks down soil structure and some soil organic matter and can cause soil compaction and too much moisture loss for germinating seed and new seedlings. Plowing should be used to prepare fields for planting wheat only when there is heavy residue left from the previous crop. Disking can be sufficient to incorporate light crop residue. If the ground is compacted from previous crops, rip the soil. The final step for seedbed preparation is to mulch or disk harrow to break up clods and make an even seedbed for planting. Leave sufficient surface mulch to prevent soil erosion in wet, rainy conditions.

## Soil Fertility

Test your soil prior to planting to determine nitrogen, phosphorous, potassium, and pH levels for recommended application rates. In general, wheat does not require much fertilizer in the common rotation systems of western Washington. If wheat follows a crop that was heavily fertilized, do not apply any fertilizer to the wheat in the fall; the wheat will take up nutrients remaining in the soil from the previous crop. Tables 2 and 3 provide general phosphorus (P) and potassium (K) application rates based on soil test results. Hard red wheat is typically fertilized at a higher nitrogen rate than soft white wheat, as nitrogen fertilization increases grain protein content which is desirable in hard red wheat but not in soft white wheat. For more complete fertilization recommendations, see Turner's *Fertilizer Guide: Winter Wheat and Barley for Western Washington* (FG0017)

If applying fertilizer in the fall, apply half the recommended fertilizer in a band at planting, but no more than 25 pounds nitrogen per acre. Apply the remaining fertilizer in the spring, when temperatures have warmed up and the crop has begun to actively grow. Broadcast a single granular application over the crop and leave on the soil surface, or apply a foliar spray. Foliar applications can be split such that the first is applied as soon as it is dry enough to move equipment through the field (March–April) and the second is applied in late spring (May). Foliar fertilizer is generally applied at a low rate (e.g., UAN 32 at 6 gallons per acre, or 21.3 pounds nitrogen per acre).

**Table 2. Suggested rates of phosphorous ($P_2O_5$) application based on band application. For growers who broadcast rather than band, *use double these rates* prior to seeding and work into seedbed (Turner et al., 1977).**

| If your soil test for P reads: *(parts per million)* | Apply this amount – lbs./acre $P_2O_5$ |
|---|---|
| 0 – 1.0 | 70 |
| 1.0 – 3.0 | 45 |
| 3.0 – 6.0 | 0 |
| 6.0 – 10.0 | 0 |
| > 10.0 | 0 |

**Table 3. Suggested rates of potassium ($K_2O$) application based on band application (Turner et al., 1977).**

| If your soil test for K reads: | | Apply this amount lbs./acre |
|---|---|---|
| Soils with high reserve K *(ppm)* | Soils with low reserve K *(ppm)* | $K_2O$ |
| 0 – 30 | 0 – 50 | 60 |
| 30 – 60 | 50 – 100 | 30 |
| 60 – 90 | 100 – 150 | 0 |
| 90 – 125 | 150 – 200 | 0 |
| > 125 | > 200 | 0 |

**Figure 1. (A) Grain drill used to uniformly seed wheat. (B) Buggy used to broadcast wheat seed. (Photos by Jonathan Roozen, Washington State University Extension)**

Wind lodging increases in taller varieties when high rates of nitrogen fertilizer are applied to wheat crops. Excess nitrogen also produces succulent, leafy growth and can increase insect and disease problems. Avoid nitrate forms of nitrogen due to their tendency to leach. Minimize the use of broadcast fertilizers to minimize weed fertilization.

### Crop Competition

A healthy, vigorous wheat crop is the best defense against weeds. Reduce weed populations by rotating wheat with crops that have a different life-cycle or a more intensive weed cultivation program. Row crops such as corn and beans are effectively cultivated for weed control and can be good crops to grow prior to wheat for this reason. Seed wheat anywhere from mid-September to mid-October to avoid heavy weed germination. The proper seeding depth and planting density are critical for rapid germination and crop establishment.

## PLANTING

Wheat is planted either by drilling or broadcasting (Figure 1). Drilling results in more uniform rows and plant stands with less lodging and better yields than broadcasting. Field size in western Washington is no more than 80–100 acres, and growers must move equipment from field to field on heavily trafficked roads. As a result, the majority of growers use 10–15-foot wide drills. Broadcast seeding is done with a buggy and requires uniform seed application followed by incorporation with a mulcher or harrow. For small-scale growers, broadcast wheat with a hand-held seed spinner and then incorporate seed into the soil with a garden rake.

### Winter Wheat

Do not plant winter wheat in the spring, as prolonged exposure to cold temperatures are necessary for head initiation, referred to as vernalization. Plant winter wheat in mid-September to mid-October before temperatures become too cold for good plant establishment. September 25 is a good target date for planting. Planting earlier than September 15 may result in greater exposure to stripe rust, leaf rust, yellow dwarf virus, Hessian fly, and “take-all” root rot.

### Spring Wheat

Plant spring wheat as soon as fields are dry enough to be worked, usually March or April. The earliest planting date is best for optimum crop yield. Alternatively, planting spring wheat varieties in the fall will allow the same harvest time as fall-planted winter wheat.

### High Quality Seed

Start with a high quality seed lot that has a high germination rate and is free of disease, weed seeds, and other trash. Weed-contaminated

wheat seed is the most common means by which weeds are introduced into a wheat field. Certified seed is recommended because it is tested for germination and is weed seed free; while it is slightly more expensive than non-certified seed, the extra cost may be significantly less than the cost of additional weed control.

Seed treatments may be critical for good stand establishment and crop development due to seedborne and seedling diseases that thrive in the wet, cool climate of western Washington. See *Seed Treatment for Small Grain Cereals* (OREM 8797) for specific seed treatment recommendations. Organic farmers cannot use synthetic fungicidal seed treatments and should therefore grow varieties that are resistant to common smut and other seedborne diseases.

### Seeding Rate

Seeding rates vary by seeding date, available moisture and fertility, weather outlook, and seeding method. Winter wheat and spring wheat should be drilled at 100–120 pounds per acre. When broadcast seeding, you may need to increase the rate up to 150 pounds per acre depending on how well seed is incorporated. Mid and late September seeding should be at the lower seeding rate, while October seeding should be at the higher rate to ensure a good plant stand. It is important to have uniform plant distribution for efficient use of available resources such as fertility and moisture and to provide optimal crop competition for weed control.

### Planting Depth

Plant seed at 2–3 inches below the soil surface and ensure good soil contact to prevent water accumulation around the seed and subsequent seed rot, in addition to encouraging rapid seed germination and plant emergence and good stand establishment. A poorly prepared seedbed will result in non-uniform seeding depth, poor seed-to-soil contact, uneven stands, and increased winter injury from excessive moisture and disease. A seeding depth that is too shallow may result in damage to wheat seedlings from pre-emergence herbicide treatments and poorly established plants.

### Drainage

In western Washington, saturated fields in the late fall, winter, and early spring months can be a major limiting factor for wheat productivity. Many fields in the region have a hard pan at about 18 inches depth. Use a chisel plow or subsoiler to rip the field prior to planting to break through this hard pan and allow water to percolate down through the soil profile.

Good soil structure and soil organic matter also improve soil drainage. Due to low field elevations and high rainfall, the water table in many fields is very high. Seasonal in-field V-ditches and permanent perimeter ditches are needed to increase water drainage. Farmers use V-ditchers (Figure 2) to create shallow ditches in low spots in fields to remove excess water and fill them in when they are no longer needed in the drier spring and summer months. Some wheat varieties may be better suited to wet soil conditions than others.

**Figure 2. V-ditcher used to dig ditches through fields to improve drainage during winter rains. (Photo by Jonathan Roozen, Washington State University Extension)**

## HARVESTING

Winter wheat is usually ready for harvest by mid-August throughout western Washington. Spring wheat is ready for harvest by late August to mid-September, depending on cultivar maturity (early, mid-season, or late) and climatic conditions, especially late-season rains and temperatures.

## Cutting and Feeding

In western Washington, wheat grain is ready for harvest when it reaches 13–16% moisture. Due to the cool, humid, maritime climate, lower grain moisture can be difficult to reach in the field. Combine harvesters are the primary tool to cut and thresh wheat crops (Figure 3); however, some small-scale producers prefer to swath (windrow) their crops and allow to dry in the sun before threshing with belt headers on combines. This system reduces the need to change to a header with a sickle cutter, thereby allowing small-scale producers to rely on existing equipment.


**Figure 3. John Deere harvester used for cutting and threshing wheat. (Photo by Jonathan Roozen, Washington State University Extension)**

When using a sickle cutting header, make sure the blades are sharp. Dull sickle blades will tear at the stalk, causing the grain to shatter. Set the height of the header to gather all of the grain while minimizing the volume of straw that is cut. Many growers in western Washington leave as much straw as possible in the field because it is an important source of organic matter and nitrogen.

The height of the crop will change over the field, and the combine operator will need to change the header height accordingly. The reel should be adjusted just slightly ahead of the cutter bar and low enough to make good contact with the top of the stems. Reel speed should be adjusted relative to ground speed so that the bats begin to lay the stems over just before they are cut. Combines, like most other machinery, are designed to operate best at a moderate ground speed (about 2 miles per hour). When ground speed is too high, some wheat may be poorly cut or knocked down. When ground speed is too slow, some stems may not drop over into the header properly and will fall to the ground underneath the cutter bar.

Small-scale wheat growers can use a hand sickle to harvest their wheat. Tie wheat into bundles, called "shocks," and stack upright in the field to dry before threshing. If the grain moisture is above 13%, dry the bundles inside to reduce moisture before threshing.

## Threshing and Separating

Setting the combine for maximum performance usually involves a tradeoff between maximizing the volume of grain harvested and the quality of the grain because the adjustments that increase threshing efficiency can damage grain (cause cracking or breakage) and increase the amount of foreign material. Damage is especially high for very dry (< 12% moisture) or very wet grain (> 22% moisture). Adjust the cylinder speed based on seed moisture to recover as much grain as possible from the cut plant. When the ground speed is very high (> 2.5 miles per hour) or when too much straw is cut, more grain is left intact on the plants and dumped back into the field with the straw. Grain that is damaged or has high amounts of foreign material brings a low price and is more difficult to store. Cracked and broken grain is more susceptible to damage by insects and storage molds, and the smaller fragments and foreign material restrict airflow during drying and storage.

Small-scale growers can purchase or share a portable grain thresher. The plot thresher is one of the most commonly used older threshers that was designed to thresh bundles or shocks of wheat. Threshers generally require 2–3 people to operate effectively. It may be possible to find such used equipment in wheat-growing areas where farmers have upgraded to new large-scale equipment.

## DRYING

Due to the high relative humidity of western Washington, harvested grain must be dried quickly to prevent spoilage. There are 2 forms of drying: batch drying and continuous flow drying. In batch drying, grain is mixed constantly with a recirculating auger that provides uniformly dried grain. More labor and time are required with this system, which includes loading and unloading the dryer. In continuous flow drying, a stream of grain passes through blown hot air and then flows through blown cool air. Because the grain passes through the drying column only once, it is often not dried as uniformly as with the batch drying system. However, large quantities of grain can be dried without stopping in continuous flow drying systems. The initial cost of this system is high and includes grain handling, careful management to obtain acceptable uniform drying, and specific loading and unloading equipment.

Natural air should be used with both types of drying to reduce over-drying which can cause the grain to crack or burn. If the initial moisture content is high, dry the grain quickly to prevent the top layer from spoiling. The relative humidity and temperature of ambient air vary throughout the day, and final grain moisture content will be a function of the average air conditions. If the grain is to be sold immediately, dry to 12–13% moisture to retain the maximum total weight and not be charged a penalty. If the grain is to be stored, dry to 12–13.5% and maintain between 60°F and 70°F to avoid condensation.

## STORAGE

If wheat is dried or stored on-farm, use a properly designed and constructed storage bin to minimize handling losses and maintain quality during storage. A good grain storage system provides a controlled atmosphere, aeration, weather-tight protection, pest protection, and access for easy and complete cleanout (Figure 4). Because all these factors prevent dockage from mold, insects, and sprouting, each should be of high priority when selecting a grain storage system.

**Figure 4. Facility used to dry and store wheat. (Photo by Jonathan Roozen, Washington State University Extension)**

Cylindrical metal bins are the most common structures used for grain storage because they are effective and affordable. Before harvest, thoroughly clean each bin to remove all traces of the previous crop from pits, augers, transitions, and any other locations in the grain handling system where grain can accumulate. If there is evidence of storage pests, take control steps before filling the bins with newly harvested grain.

## PEST MANAGEMENT

Weeds, diseases, and waterfowl are primary pest concerns in western Washington. While there are a few insect pests to be aware of, they are not significant on most farms unless they have been allowed to build up due to poor rotations. The following provides an overview of the most common pest problems that occur in the region. Also included are recommended management practices. For a complete guide to management for any of these pest problems, refer to the Pacific Northwest handbooks on insects, weeds, and plant diseases, available on the Web at http://ipmnet.org/plant-disease/index.cfm. Before applying a pesticide, always read the label and follow those directions.

### Weed Management

Weeds compete with wheat for space, nutrients, moisture, and sunlight, thereby reducing wheat yields. Just as importantly, harvested grain that

is contaminated with weed seeds has a lower quality and brings a reduced price. For these reasons, it is important to effectively manage weeds.

The main weeds of concern in western Washington are annual broadleaf weeds such as chickweed *(Stellaria media)*, groundsel *(Senecio vulgaris)*, shepherd purse *(Capsella bursa-pastoris)*, pineapple weed *(Matricaria matricarioides)*, wild rutabaga *(Brassica napus)*, and other species of the mustard family. Broadleaf weeds germinate in late fall or early spring at the same time wheat emerges, and thrive in the cool, moist conditions of most western Washington winters and springs.

Grass weeds such as wild oat *(Chasmanthium latifolium)*, annual ryegrass *(Lolium multiflorum)*, and quack grass *(Agropyron repens)* can also be severe problems in some areas. Within a month of planting, wheat fields can become a solid mat of weeds if adequate weed control is not practiced. Winter wheat that is seeded in early to mid-September usually has more severe weed problems than wheat seeded at later dates.

***Control.*** Successful control of broadleaf weeds and grasses involves a combination of practices. Early germinating weeds may be destroyed by tillage in seedbed preparation. Plant only clean wheat seed. Apply pre-emergence herbicides as soon as possible after planting to avoid damaging wheat seedlings. If wheat and weeds have already emerged, apply herbicide before weeds are 3 inches tall. Follow herbicide label instructions and seed wheat appropriately to avoid undue chemical damage. A good wheat stand in a clean field often will prevent or reduce emergence and establishment of new weeds. *The Pacific Northwest Weed Management Handbook* (MISC0049) provides more specific chemical weed control recommendations for wheat in western Washington.

## Disease Management

Several diseases can cause significant yield reduction in wheat in western Washington. While stripe rust is the most common problem in northwest Washington, other fungal, bacterial, and viral diseases can also be significant. Today there are many disease-resistant wheat varieties available, and these should form the first line of defense.

**Stripe rust.** Stripe rust is caused by *Puccinia striiformis* f. sp. *tritici* and is a serious problem in regions that have cool temperatures and humid conditions throughout the wheat growing season. In some areas of western Washington, yield losses of up to 100% can occur due to stripe rust. The primary source of stripe rust inoculum in the region is the previous wheat crop or volunteer wheat seedlings in nearby fields. Spores that cause the disease can travel hundreds to thousands of miles via winds and jet streams.

While some perennial grasses such as cheat grass and western wheatgrass (*Bromus* spp.) can serve as a reservoir for inoculum, wheat is the only significant host. In the fall, wind carries fungal spores (called urediniospores) to newly emerging wheat. The spores germinate and infect new wheat seedlings when adequate moisture is present, which is the case in western Washington almost all year round. After infection occurs, the disease increases slightly and then overwinters on the wheat plants. Stripe rust begins to rapidly increase in the early spring growth (late February–April) when temperatures are between 50°F and 60°F. This disease may appear earlier than other rusts because it can develop at cooler temperatures. Disease growth is reduced when nighttime temperatures are greater than 65°F or there are several consecutive days when temperatures reach the mid-80s.

Stripe rust symptoms are bright yellow-orange pustules arranged between leaf veins in stripes (Figure 5). However, stripe rust pustules do not form stripes on seedling leaves. Symptoms become evident in late spring and early summer (May–July). The spores usually come off if you rub the leaves with your fingers. Atypical symptoms for stripe rust include dead tissue spotting on varieties with resistance to some disease strains. Black telia will appear as the plant matures and temperatures rise.

**Leaf rust.** Leaf rust is caused by the parasitic fungus *Puccinia triticina* (previously referred to as *P. recondita* f. sp. *tritici*) and can only survive in living leaf tissue; it is not borne in soil or on crop residue. In the fall, spores blow to

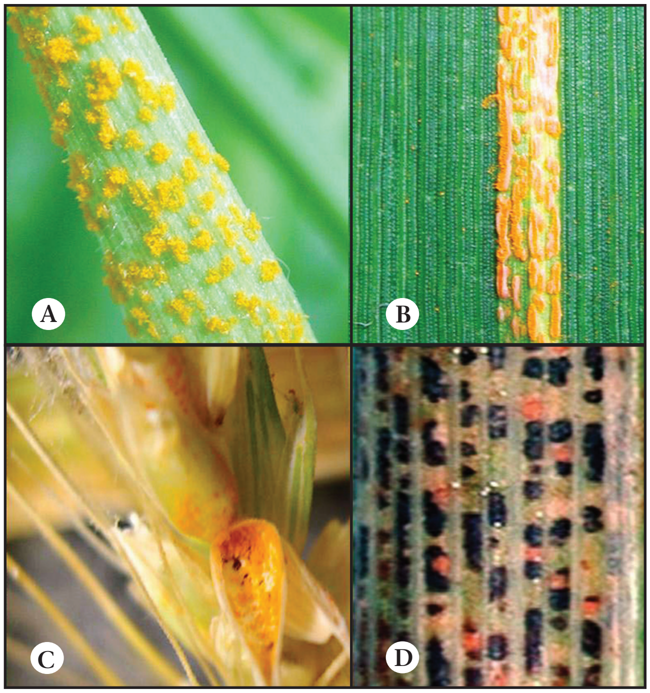


**Figure 5. Pustules of stripe rust on wheat: A) uredia and mass of urediniospores on seedling leaf; B) adult plant leaf showing distribution in longitudinal stripes; C) inside and outside of glumes and on immature kernels; and D) leaf sheath showing black telial pustules along with orange uredial pustules. (Photos by Xianming Chen, USDA-ARS)**

newly planted wheat. Wheat planted in early September can sustain heavy leaf rust infection and may turn yellow to brown in the fall, but this does not seem to cause winterkill. Leaf rust survives the winter as latent infections on green leaves. In the early spring, the fungus within leaf tissue start sporulating, producing brown pustules called uredia which erupt to release fresh urediniospores that blow to new leaves.

Dispersal of spores is favored by dry, windy conditions, while infection requires moisture, which can be provided by rain or dew. Heavy rain is generally unfavorable for rust because it tends to wash the spores off the leaves, but can provide conducive moist conditions afterward. Infection can occur in as little as 4 hours during favorable weather (temperatures between 60°F and 77°F with good dew). Leaf rust severity increases exponentially over time and can appear to suddenly explode when daytime temperatures reach between 70°F and 85°F, usually in May in western Washington. If weather conditions are moist and warm, leaf rust can increase even more rapidly than stripe rust. In the late summer, leaf rust survives on volunteer wheat. Although some strains of leaf rust can survive on jointed goatgrass or wheatgrass, they appear to be different from the strains that attack cultivated wheat. Alternative hosts are not important in the wheat leaf rust life-cycle.

Leaf rust pustules are small (about 1/32 inch long by 1/64 inch wide), but usually bigger than stripe rust pustules (Figure 6). Compared to stripe rust pustules that are elongated and yellow to orange, leaf rust pustules are relatively rounded and dark orange to brown. Leaf rust pustules do not form stripes as stripe rust does on adult plant leaves because a single spore infection of leaf rust generally produces only 1 pustule, while that of stripe rust produces several to thousands of pustules. In some cases, leaf rust pustules are surrounded by a narrow yellow or white halo. Small brown closed pustules may appear on culms and heads.

The pustules contain masses of powdery orange to brown spores that often spill out and form a grainy brown dust on the leaf surface around the pustule. When rust severity is high, field scouts may notice the brown dust on hands and clothing, similar to the yellow to orange dust of stripe rust. As leaves age, pustules begin to produce black spores that appear greasy and are most easily seen on the lower leaf surface and leaf sheaths. Leaf rust typically occurs uniformly

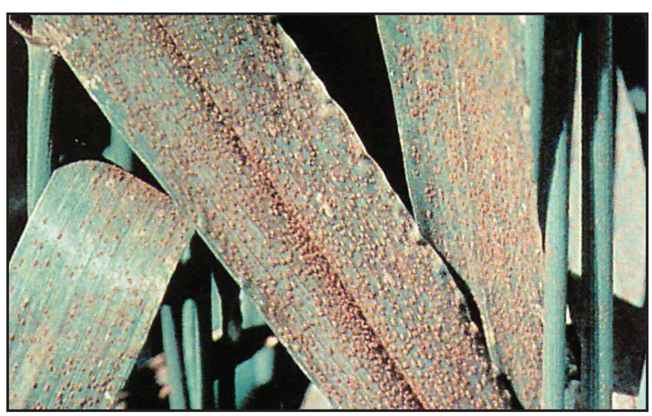

**Figure 6. Random distribution of leaf rust pustules on wheat leaves. (Photo by Xianming Chen, USDA-ARS)**

across a field as the disease progresses. In overwintering locations, symptoms are most severe on the bottom leaves. In a newly infected field, symptoms appear first on upper leaves.

***Cultural control.*** The following adjustments to your growing practices are recommended to help prevent stripe and/or leaf rust:

- Use only plant varieties with at least a moderate level of resistance to the rusts. (New races develop rapidly and within 3 years of release can often overcome varietal resistance. A total of 138 races of stripe rust have now been identified, and each year, 25–40 can be found in the United States. The number of races detected in western Washington is higher than any other region in the United States almost every year.)
- Plant in mid to late September (no earlier than September 15) to reduce the green bridge of host plants whereby stripe rust moves directly from one plant to the next.
- Scout winter wheat in the fall and spring for stripe rust. Examine the fence rows, ditch banks, and other areas with perennial grasses. Perennial grasses such as *Bromus* spp. are often actively growing when the cultivated crop is dormant and may be important green bridge plants.
- Eliminate volunteer wheat from fields and in field margins to control inoculum.
- Use low rates of nitrogen fertilizer. (High rates of nitrogen fertilizer delay wheat maturity and therefore expose the plants to longer infection periods; and second, a more favorable rust environment is created through increased lodging.)

***Chemical control.*** Use the following points as a general guide for whether to apply a fungicide to eliminate existing stripe and/or leaf rust:

- Rust on lower plant leaves increases potential yield loss.
- Rust on wheat in neighboring fields is a likely source of inoculum for surrounding fields.
- Cool (45–60°F), wet weather from mid-May to mid-June favors rust development.
- Susceptible varieties are more likely to require a fungicide treatment.
- A 2–5 bushel per acre yield increase is generally needed to pay for the fungicide application, which costs $15–20 per acre.

In western Washington, especially the Skagit Valley, the weather conditions are almost always favorable for stripe rust infection and development. Susceptible wheat varieties always require fungicide applications to reach optimum yield potentials. Moderately resistant varieties (such as Stephens winter wheat and Alpowa spring wheat) that provide adequate rust resistance in eastern Washington can have substantial yield losses (5–20%) in western Washington.

**Powdery mildew.** Powdery mildew is common on wheat in western Washington, especially in early spring. However, there is no evidence to suggest it causes significant crop damage or yield reduction. We include discussion here only because farmers and others are frequently concerned about it.

Powdery mildew of wheat is caused by the fungus *Blumeria graminis* f. sp. *tritici*. Wheat is the only host for this disease. Although similar powdery mildews occur on other small grains and many grasses, these mildews are other strains of the species *B. graminis*.

Powdery mildew is easy to diagnose, as it forms patches of a white to gray, powdery coating on leaf blades, sheaths, stems, and heads (Figure 7). Chlorotic patches develop on infected leaves, but often the tissue directly under the fungus remains green. This pattern of symptom development is called the “green island” effect. Lower leaves are usually the most severely infected because of the high humidity around them.

The powdery mildew fungus overwinters in western Washington on infected plants and wheat residue. Wind carries spores to new plants in the early spring, causing primary infection. High humidity causes spore germination and infection. Heavy, lush growth favors the disease by promoting high humidity through the plant canopy. Unlike rusts, free water is not needed for powdery mildew to advance; instead, this fungus produces new conidia that are dispersed

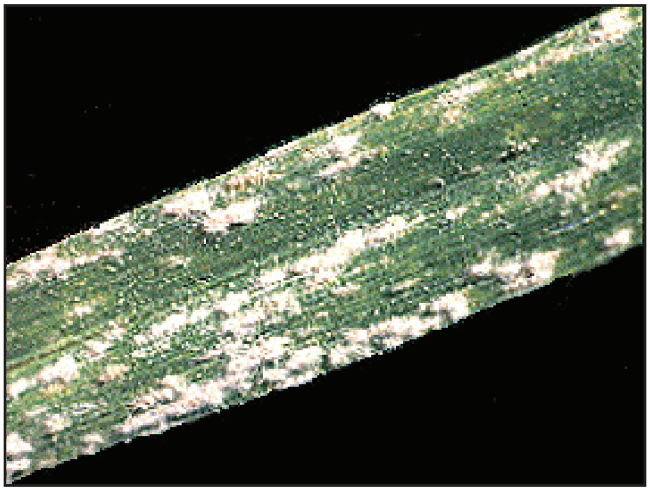

**Figure 7. Powdery mildew on a wheat leaf. (Photo by Erik L. Stromberg, Virginia Tech)**

from the plant surface by wind and rain to cause the secondary disease cycle.

***Control.*** Powdery mildew is not considered economically important in Washington, and control is not required. However, fungicides that control stripe and leaf rust also control powdery mildew. Use of resistant varieties is the best defense.

**Smut.** Until the mid-1950s, common smut, also called common bunt, was considered the most serious wheat disease in Washington. It was not uncommon to see large, black clouds of smut teliospores billowing up behind combines when infected fields were harvested. These spores are foul-smelling (they have a fish oil–like odor) due to the plant biochemical trimethylamine, and thus are referred to as one of the "stinking smuts." During harvest of heavily infected fields, sparks from the high oil content can ignite the grain and cause combines to explode. The disease greatly reduces harvest yields and causes further losses due to grain contamination.

Common smut is caused by *Tilletia tritici* and *T. laevis*. In Washington, *T. tritici* is more prevalent, while *T. laevis* is more common in the central and eastern United States. Infection occurs in the seedling stage before tillering occurs and is systemic, thus all tillers become diseased. The first obvious symptoms of common smut occur after heading. Infected heads remain green longer than healthy heads but have a gray-green hue. The kernels are replaced by "smut balls," which are full of spores, rounded, and cause the glumes to spread abnormally, giving the heads an asymmetrical appearance (Figure 8). Plant stunting may not be noticed. Teliospores released from the smut balls during harvest are either carried on the seed or remain in the soil where they remain viable for about 2 years.

Soil-borne and seed-borne inoculum are important factors of contamination for the next wheat crop. Teliospores germinate in moist soil and produce secondary basidiospores when temperatures are between 40°F and 60°F. Basidiospores then germinate near or on the seed and infect the developing plant coleoptile before it emerges from the soil (seedling infection). Mycelium develops in the meristematic tissue of the growing plant and is carried upward with plant growth. At flowering, the fungus colonizes the ovaries, replaces the kernel with teliospores to produce easily ruptured smut (bunt) balls, and the cycle begins again.

**Figure 8. Smut that has affected wheat kernels and head formation. (Photo by Jim Stordahl, University of Minnesota Extension)**

***Control.*** Some new commercial varieties have resistance to common smut. However, a newly released resistant variety will last only 5–8 years before a fungal strain develops that can attack it. Certain seed treatments help

control seed-borne and soil-borne common smut. Even though most modern commercial varieties are resistant to common smut, seed treatment is advisable to prolong their effective life and delay development of new pathogenic races.

**Take-all or crown rot.** Take-all is a fungal disease caused by *Gaeumannomyces graminis* var. *tritici*. It is soil-borne and thrives in wet conditions and poor soil. Take-all incidence can become severe when wheat follows wheat or grass. Affected plants will abort tillers of 3 leaves or less. In dry or moist, warm soils, take-all may cause delayed seedling emergence, significant stand loss, and premature grain ripening, resulting in reduced yield. Heavy use of nitrate nitrogen fertilizers may increase the amount of this disease.

Take-all is characterized by gray or black scurf or "stroma" on inner leaf surfaces at the base of the plant where tillers join (Figure 9). To see this, remove the plant from the ground, keeping the roots intact, cut the crown in half longitudinally, and pull off the outer leaves.

**Figure 9. Take-all or crown rot–infected roots on the right and non-infected roots on the left. (Photo by Richard Smiley, Oregon State University Extension)**

***Control.*** Rotate wheat with non-susceptible crops for 2 or more years to most effectively control take-all. Delay fall planting and avoid barley in the rotation to minimize the disease. There are no resistant varieties.

## Insect Management

Few insect pests affect wheat in western Washington. However, if wheat production expands and poor management practices are used, more problems can be expected.

**Aphids.** The Russian wheat aphid, *Diuraphis noxia* (Hemiptera: Aphididae), was first found in the United States in 1986 and is currently documented in 16 western states, including Washington. Russian wheat aphids can build up high numbers and cause significant plant damage. Nymphs and adults feed on foliage and grain spikes of actively growing plants with piercing–sucking stylets. While feeding, these aphids can transmit a toxin that causes discoloration and distortion of the plant. Heavily infested leaves have longitudinal white, purple, or yellow streaks. Aphid feeding can prevent normal unrolling of leaves, plant and head stunting, and bleached heads with poorly formed grain. In some cases, grain heads never properly emerge because the awns trap the flag leaf.

Russian wheat aphid adults are small (1.6–2.1 mm long), spindle-shaped, lime green in color, and have a "double cauda" which is a modified structure of abdominal tergum in adults varying from elongated to short and fingerlike to triangular as seen from the side (Figure 10). The western wheat aphid, *D. tritici*, is similar in appearance and also causes damage to wheat, but has a regular cauda and is covered with wax. No male Russian wheat aphids have been found in North America, so no sexual propagation of this species is believed to occur in the region. Females reproduce asexually, giving birth to live young. On average, a female matures in 7–10 days and lives for 60–80 days. Development rates are greatly influenced by temperatures, with optimal growth at 86°F. Russian wheat aphids are cold-tolerant, surviving temperatures as low as -13°F. In western Washington, Russian wheat aphid can survive all year long. Quick freezes and extended periods of snow cover reduce winter survival.

Russian wheat aphids produce several generations of winged forms each year. However, they are not strong flyers. Peak aphid movement is in July, when they move from summer grain crops

**Figure 10. Russian wheat aphid. (Photo by Phil Sloderbeck, Kansas State University Extension)**

such as spring wheat and barley and begin to infest maturing winter wheat. Volunteer wheat and barley play an important role as refuge crops between summer harvest and fall crop emergence. Cool-season grasses such as crested wheatgrass, intermediate wheatgrass, and Canada wild rye serve as alternative hosts. In addition, Russian wheat aphid can survive on fescue grass, foxtails, wild barley, and Bermuda grass.

***Control.*** The economic impact of Russian wheat aphid in winter wheat is such that 1% of infested tillers equals 0.5% yield loss. In general, fields with greater than 10% infested tillers benefit from an insecticide application. Monitor infestation levels by sampling weekly. In each field, check at least 10 plants in 5 different areas. Consider applying an insecticide in the spring if:

- 10% of plants are infested prior to flowering
- 10% of tillers are infested at the beginning of flowering
- 20% of tillers are infested at the early milk stage

Chemical control of Russian wheat aphid is effective only if complete coverage is achieved. Low temperatures, poor coverage, insufficient spray volume, and drought stress reduce spray efficacy. If outbreaks are persistent, consider using a systemic product. If fields have a history of infestation, consider using a seed treatment on the next wheat crop.

**Hessian fly.** The Hessian fly, *Mayetiola destructor* (Say) *Cecidomyiidas*, was introduced to North America from Europe in the 1700s. Today in the United States, Hessian fly can be found from Nebraska to the Atlantic, from Maine into the Piedmont areas of North Carolina, South Carolina, Georgia, and in isolated areas west of the Rockies, including western Washington. Severe losses have been reported in Washington, Texas, Nebraska, Kansas, and Indiana. By 1933, the fly occurred all along the western Cascade Mountains.

Hessian fly infestations have been largely restricted to the irrigated Columbia Basin fields and dryland wheat fields closely located to irrigated areas. While wheat is the primary host plant, Hessian fly is also found on rye, barley, and other wheat-related species. Of the 6 known Hessian fly races (biotypes), at least 2 are likely to occur in any area where wheat is grown. Hessian fly occurs most frequently when wheat is directly seeded following wheat.

The Hessian fly has 4 life-cycle stages: egg, larva (maggot), pupa, and adult. Larvae hatch from the eggs within 3–10 days and migrate down the leaf to the crown of the seedling or the node in jointed wheat. The larvae feed for about 2 weeks and then develop to the pupa stage. Adults emerge a short time later, depending on the weather and time of year. The adult lays eggs on wheat leaves during its 4-day lifespan. They prefer to lay eggs on newly emerged and very young wheat plants in preference to older wheat plants and alternate hosts.

The adult Hessian fly is a small, dark, long-legged, 2-winged insect which resembles a mosquito. The female fly is about 4 mm long and has a distinct reddish tinge. The male fly is 2.5–3.5 mm long, brown or black in color, and has 2 pairs of abdominal claspers. The egg of the Hessian fly is thin, cylindrical, and 0.4–0.5 mm long. Eggs are glossy red when laid and gradually become deeper red at one end and opaque white at the other. The newly hatched larva is red for 4 or 5 days and then turns white. As the larva matures, a translucent green stripe appears down the middle of its back. The full-grown larva is 3.5–5.5 mm long and about 1 mm wide. The pupa is brown-headed with a white body

that has a reddish tinge. The pupae over-winter within a spindle-shaped puparium, which is the hardened skin of the last instar larva. The puparium is red to dark brown in color and 2.5–6.2 mm in length. The appearance of this structure has earned it the name of “flaxseed” because of the similarity in size, shape, and color. The puparium is found just below the soil surface near the crown of wheat plants.

In Washington, the Hessian fly completes 2 or 3 life-cycles each year: 1 or 2 in the spring and 1 in the fall. The first spring emergence begins as temperatures reach a mean of 45–50°F, commonly after April 1 (depending on the area and seasonal variations). The second generation typically emerges between May and June. The fall emergence normally takes place between late August and mid-October. Larval activity generally ceases about mid-October with the onset of cold weather.

Each generation of Hessian fly emerges and develops over a wide range of time. There are always some larvae of the spring generation(s) that over-summer and emerge in the fall, or continue to over-winter in the stubble and emerge the following spring. Similarly, some larvae of the fall generation do not emerge in the fall and may over-winter until the next spring. Delayed emergence is a survival mechanism of the insect to maintain itself through unfavorable environmental conditions.

**Figure 11. Adult Hessian fly. (Photo by Scott Bauer, USDA-ARS)**

***Control.*** Plant winter wheat in mid to late September to avoid fall Hessian fly infestation.

## Waterfowl Management

Damage by waterfowl (ducks, geese, swans, and cranes) can be a major problem in areas where birds over-winter or have migration routes. Waterfowl affect wheat in a number of ways. During the winter, waterfowl graze on wheat seedlings and can substantially decrease plant stand. Soil compaction can result when large flocks of waterfowl use a field for a sustained period, resulting in reduced water infiltration, soil aeration, and crop yield. In late summer, grain consumption prior to harvest is a major source of loss. Contamination from waterfowl feces causes a major loss post-harvest. Additional grain is lost through trampling.

Snow geese and swans cause the most damage to wheat in western Washington due to the size and impact of their flocks that can be up to 100,000 birds. Damage occurs mostly from October to January while the geese and swans are in the area and wheat is in the early stages of growth.

***Control.*** A number of techniques can be used to scare waterfowl from wheat fields. Studies indicate that a combination of 2 or more techniques dramatically increases effectiveness. Deterrent flags are commonly used by interspersing throughout a field to discourage waterfowl landing. Because flags are easy to make, they are the cheapest and most successful of all control techniques currently used. While black appears to be the most effective flag color, any object that moves with the wind and produces an unnatural noise can deter waterfowl.

Propane guns are commonly used as a scare device; however, this deterrent has come under conflict due to the rising human population in western Washington. Many newcomers to the area do not understand the importance of a farmer protecting their wheat crop and complain about cannons that fire at a set time. To relieve complaints, some farmers in western Washington are experimenting with newer cannon technology that can be attached to a laser which triggers guns to fire when waterfowl break the beam. One gun for every 50 acres is sufficient. Hunting is also an

effective control option, although snow goose season rarely goes as long as wheat needs protection. However, just the noise from firearms usually disperses waterfowl. Shots should be fired in the air near waterfowl concentrations to move them from fields. Other bird dispersal methods include the use of falcons and enticing native bald eagles to area fields.

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